Sell It Now or Later? A Decision-making Model for Feeder Cattle Selling

A Thesis

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ABSTRACT

We study the decision-making process of the selling of feeder cattle. For a specific feeder cattle, we strive to answer the following question: whether to sell the cattle in spring or fall to maximize the profits of farmers? To this end, we first construct an empirical pricing model based on a series of related covariates including: market conditions, lot characteristics, quality characteristics, color and seasonality. Then, based on the empirical pricing model, we estimate both the profits of selling the cattle in spring, and in fall. Comparing the two expected profits, we can help guide the decision making of farmers. By applying our decision-making method to a real-world feeder cattle market dataset, we show that 55.33% of the cattle sold in fall can bring more profits if they could be sold in spring.

BIOGRAPHICAL SKETCH

Minhao Yan was born in Zhangjiakou, Hebei Province, China on September 25^{th}, 1994. Upon matriculating at Nankai University, she chose Industrial Engineering in Business School as her major with a special interest in the use of stochastic modeling and mathematical analysis. Her studies at the university have been interdisciplinary with an emphasis on statistics, computer science and management, and have been highly relevant to improving the efficiency of industrial systems. She was a straight-A student, and by her efforts she earned two high-level scholarships at Nankai University.

In the spring semester of her junior year she was granted the privilege to study as an exchange student at Taiwan's National Tsinghua University. After the first semester, she was invited to participate in a summer research program evaluating the efficacy of special medical insoles as well as proposing schemes for improvement, and was awarded “Outstanding Individual Certification”.

After earning her Bachelor's degree of management and graduating from college, she was accepted into the Industrial & System Engineering program at Texas A&M University (TAMU). During her graduate study, she conducted several research projects in decision-making, high-dimensional statistics analysis and machine learning. Her paper “Partially Linear Additive Gaussian Graphical Models” was accepted by ICML (International Conference on Machine Learning) in 2019.

In 2018, Minhao was admitted by Master of Science program in the Department of Applied Economics and Management at Cornell University. She works with Professor Miguel Gomez and Professor Todd Schmit. They conducted a research project on a decision-making model for farmers to choose the optimal time to sell feeder cattle.

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My gratitude towards the mentorship from Professor Todd Schmit and Professor Miguel Gomez is far beyond my expression. Their enthusiasm challenges and inspires me to work on this problem and thus to finish this project. During my master study, the generous support and huge influence from Todd and Miguel have been constitutional for my research and study, and is the greatest fortune that I can ever imagine as a researcher, and will always guide me to pursue my future research.

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I am especially grateful for Sinong, who has supported me a lot in both research and life, and is always the first reader for my works.

Finally, I would like to thank Cornell University to provide such an excellent environment for me to do research. My work cannot be finished without the support of my department. They not only provided the technical method for me, but also the dataset we used in our work. I am very proud to be a member of my department.

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CHAPTER 1. Introduction

1.1 Background

The United States has not only the largest cattle industry in the world, but also the world's largest produce industry of beef, providing high-quality beef for domestic and export use. The U.S. beef industry is roughly divided into two production sectors: cow-calf operations and cattle feeding: cow-calf operation is a process of raising farmer's permanent herd of cows to produce calves for later sale; the cattle feeding industry depends on feed grains, forages and other inputs to support product process.

The predominance of cattle feeding operations are mainly located in the Great Plains, Corn Belt, Southwest, and Pacific Northwest. Beef feedlots are the places to feed cattle that raise feeder cattle to finished animals for slaughter. Feeding period varies from 90 to 300 days due to different starting weight levels, feed inputs and body conditions. The average rate of gain is about 2 pounds per day.

Feeder cattle consist of steers (castrated males) and heifers (females who have not dropped a calf). They are placed in a feedlot and be fattened prior to slaughter.

The U.S. beef industry table from 2002 to 2015 is shown in Table 1.1 summarizing averaged annual U.S. retail beef price, retail value of U.S. beef industry, total U.S. beef consumption, value of U.S. cattle and calf production and beef production. It provides the information of the finished cattle price and quantity of finished cattle from 2002 to 2015. From this beef industry table, it should be noticed that the retail beef price, the value of U.S. beef industry and the value of beef production are increasing during these years. However, the total U.S. beef consumption is not increasing. This interesting phenomenon may relate to the price of beef (finished cattle). Also, the price of finished cattle has high correlation with feeder cattle price. Therefore, we concentrate on the price analysis of feeder cattle.

After analyzing the factors those influence the feeder cattle price, we find that the feeder cattle prices in spring are always higher than the prices in fall. Therefore, if the farmer in fall season could raise his feeder cattle for six month and then sell them in next spring, he may earn more money. However, we still need to consider the weight discount and feeding input. The weight discount is the situation that heavier feeder cattle will have lower price, since it cost more to gain one pound for heavier cattle. After considering all these premium and discount situations, we develop a decision-making model based on pricing analysis to estimate the profits of selling feeder cattle in spring or fall to help farmers choose the optimal selling time.

Table 1.1 U.S. beef industry from 2002 to 2015

Year	U.S. retail Choice beef price ($/lb)	Retail value of U.S. beef industry ($ billion)	Total U.S. beef consumption (billion lb)	Value of U.S. cattle production ($ billion)	U.S. beef production (billion lb)
2002	3.32	60	27.9	27.1	27.09
2003	3.75	63	27	32.1	26.24
2004	4.07	70	27.8	34.8	24.55
2005	4.09	71	27.8	36.6	24.68
2006	3.97	71	28.1	35.6	26.15
2007	4.16	74	28.1	36	26.42
2008	4.33	76	27.3	35.6	26.56
2009	4.26	73	26.8	32	26.07
2010	4.4	74	26.4	37	26.41
2011	4.81	79	25.5	45.2	26.28
2012	4.99	85	25.8	48.2	26
2013	5.29	88	25.5	48.5	25.7
2014	5.97	94	24.7	60	24.2
2015	6.29	105	24.8	60	23.7

**BSE was confirmed in the U.S. cattle herd in late December 2003.*
Sources: USDA, Economic Research Service, World Agricultural Supply and Demand Estimates, and National Agricultural Statistics Service.

1.2 Literature Review

The proposed decision making model is based on an empirical pricing analysis. Therefore, to start with, we review the existing literature on pricing analysis of feeder cattle. Feeder cattle prices are determined by the interaction of many factors. Some of these factors are related to the environment, such as weather conditions and feed material price. Others factors are weight, lot size, health, muscling, frame size and horn status, which can be controlled by the producer (Schroeder et al., 1988). According to Merle D. Faminow and Russell L. Gum's research in 1986, the sharp reduction in marginal value above 450 pounds will possibly influence rancher's production decisions. As a result, we believe that weight plays a very important role for feeder cattle price or value: if the feeder cattle gets heavier, its price will decrease since it costs more for heavier feeder cattle to gain one pound compared with lighter cattle.

Further, the discovery of feeder cattle prices involves the interaction of many factors: price differentials among lots of feeder cattle should reflect differences in supply and demand of the cattle in various weight and grade categories (Marsh; Buccola and Jessee, 1980); the price should reflect the demand for and value of the product's characteristics (Ladd and Martin, 1978). Specifically, the Agricultural Marketing Service of USDA (U.S. Department of Agriculture) has developed three general value determining characteristics - frame size, thickness and thriftiness which can be used to describe feeder cattle. Calves in value-added programs sell for greater prices, compared to the calves that are not weaned and vaccinated (King and Seeger, 2004a, b; Corah et al., 2006). The price advantage for calves in value-added programs has been increasing in recent years (King and Seeger, 2004b). The value-added program is called preconditioned. Precondition program is a period that farmer will build a health environment for weaned calf prior to sale. Preconditioning can reduce incidences and morbidity cost effectively. These factors suggest that preconditioning efforts create value for the entire supply chain (Nyamusika et al., 1994; Busby et al., 2004; Dhuyvetter, Bryant, and Blasi, 2005; Lalman and Mourer, 2014).

However, all these works we mentioned above do not base on New York State. Most of their data are from Kansas and Missouri which has the limitation that it only suits the condition in these two states. If we use the entire model without modifying in New York State, the result may not be accurate. Therefore, our first objective of this study was to determine how the lot characteristics, feeder cattle quality, market and seasonality factors that affect the price of feeder cattle in New York State.

Many market variables like live cattle future price, corn future price, feeding margins, variation of corn futures and variation of live cattle futures in past 21 weeks are also considered into feeder cattle price analysis (Kevin Dhuyvetter, 2000; Jing Qian, 2014). We also add market variables in our pricing model. In Dhuyvetter and Jing's pricing model, interaction effects between weight and all variables (lot characteristics, market characteristics, feeder cattle quality characteristics and seasonality) are included. Different from Kevin Dhuyvetter, 2000; Jing Qian, 2014, we only include the interaction effects between weight and feeder cattle quality characteristics, since feeding margins, variation of corn futures, variation of live cattle futures, color, lot size and month will not change when the feeder cattle weight varies. There is no need to add the interaction effect between these variables. Thus, we only consider the interaction effect between feeder cattle weight and feeder cattle quality characteristics (frame size, muscle condition, precondition, horn, thrifty and sex).

It has been noticed that the feeder cattle price in spring season is always higher than that in fall season (Kevin Dhuyvetter, 2000; Jing Qian, 2014). So, if farmers could keep their feeder cattle from fall to next spring, they may earn more money. However, feeder cattle will grow heavier during this several months, which will have a negative effect on feeder cattle price, and there is also feeding cost during this period. To deal with this decision-making problem, we build a decision-making model for farmers to estimate the profits in fall and spring, in order to help farmers choose the optimal selling time.

Various of works have studied the decisions making problems for feeder cattle. Xuecai Wang and Jeffrey Dorfman study the benefits of combining stockering the cattle with some hedging strategies in 2001. However, the provided methods may not be helpful enough for small farms considered in our work, since the hedging methods are often not available for small farms. Another related research conducted by Brad White in 2007 proposes methods to evaluate the price signals for farmers to make selling decisions on a farm-level. On the other hand, we focus on the cattle-level decisions, and strive to make a sell-or-retain decision for every cattle for each farmer. Therefore, to the best of our knowledge, our work is the first attempt to deal with the cattle-level selling decision making for feeder cattle specifically for New York state, and will be help farmers to gain more profits in the practical decision-making process.

1.3 Objective

We aim to provide supports to farmers on their decision making regarding whether to sell the cattle in fall or spring. On this purpose, the problem is especially challenging, since at each time point, both the current expected profits and the future expected profits need to be well studied. We consider three parts in the profit: different feeder cattle prices in fall season and spring season, weight discount during feeding period and feeding cost. Specifically, we should be able to conduct price analysis not only at the current time, but also for the future, which requires a robust and accurate pricing analysis method. Further, other than pricing analysis for the future, the decision-making problem demands a careful analysis on the change of the considered covariates, especially the cattle characteristics, such as the weight, and the market conditions like the future prices of cattle.

To deal with the factors that influence the feeder cattle price, a pricing analysis method is provided based on a linear model including all the interested covariates and interactions. Further, a future cost estimation is provided by empirically analyzing the history data. Finally, we proposed our decision-making model by comparing the profits of selling feeder cattle in fall and spring. Specifically, our contributions are summarized as threefold. First, pricing analysis of feeder cattle prices is conducted to study the effect of weight, lot size, wean, precondition, horns, sex, color, frame, muscle, thriftiness, season and market conditions on the feeder cattle price. Second, a decision-making method in terms of when to sell the feeder cattle is suggested. An R function that efficiently implements the method is included for other future practical applications. The function outputs are the expected profit gains of selling the feeder cattle in fall compared with selling it in next spring, while the inputs are the conditions of the cattle, the farm characteristics and the market environment characteristics. Third, the decisions of farmers in the Finger Lakes Livestock Exchange feeder cattle auction dataset are evaluated. The results suggest that the 55.33% of the cattle sold in fall can bring more profits if sold in spring.

Finally, we build a decision-making tool for farmers to make their decision. In order to find the optimal time of selling feeder cattle through this tool, the farmer should input his feeder cattle quality characteristics (muscle condition, frame size, thrifty, horn, sex, color, precondition or not), lot characteristics (lot size, feeder cattle weight), market characteristics (live cattle future price in fall and spring, corn future prices, feeding margins, coefficients of variation of live cattle futures and corn futures) and two time points farmers want to compare. (The specific explanation of each variable we mentioned will be introduced in chapter 2 model part). Farmer can also input their specific feeding cost to make the result more accurate. After inputting all these specific feeder cattle characteristics, our decision-making tool will output two profits in the two-time points, and the distance between these two profits. It is very easy for farmer to use, and the result is very straightforward.

CHAPTER 2. Pricing Analysis and Decision-making Model

2.1 Pricing Model

We first consider the derivation of expected market prices of feeder cattle by following the algorithm of Dhuyvetter and Schroeder in 2000. For a competitive market, risk-averse cattle feeders are assumed to maximize expected utility, following equation (1):

$$MAX\ E[U(\pi)] = E[U(p_L q_L - r_F q_F - r_C q_C - Z)] \quad (1)$$

where

$U(\pi)$ = utility function

p_L = fed cattle price

q_L = fed cattle quantity

r_F = feeder cattle price

q_F = feeder cattle quantity

r_C = corn price over the feeding period

q_C = corn quantity

Z = other costs

Based on this utility maximizing function, we can choose the optimal quantity of feeder cattle to buy which leads to the highest profit by taking the first order condition.

Since the corn prices and fed cattle are unknown at the time of feeder cattle purchase, we will use the expected fed-cattle sale price ${p_L}^*$and expected corn price ${r_C}^*$over the feeding period, along with their second moments σ_L and σ_C. According to previous research (e.g., Antonovitz and Green 1990; Eales et al 1990; Gardner 1976), adding future prices to construct expectations and adding coefficients of variation to measure second moments of fed cattle and corn prices can better estimate the feeder cattle price. Since feeder cattle will finally become live cattle after a period of feeding, the future price of live cattle has significant effect on feeder cattle price. During this feeding period, corn is the mainly input of feeding feeder cattle. If the price of corn increases, then the feeding cost will also increase. And the variation of future price of live cattle and corns also have positive relationship with the risk. If price variation is high, there may be more risk on the market, which will influence feeder cattle price a lot. The expected live cattle futures contract has strong relationship with feeder cattle weight. Contracts used are the fifth, fourth and third distant contracts for feeder cattle weighing 300–499, 500–699 and 700–900 pounds, respectively, on the day prior to the feeder cattle sale date. Expected corn futures price equals to average of all contracts relevant over the feeding period on the day prior to the feeder cattle sale date. This rule is from Dhuyvetter, Schroeder (2000). Therefore, the risk-responsive input demand for feeder cattle (in the price-dependent form) can be specified as:

$$r_F = f(p_L^*, q_F, r_C^*, \sigma_L, \sigma_C, Z) \tag{2}$$

We also consider the average weight per head, feeding margin, lot size, sex type, preconditioned, muscle condition, frame size, thriftiness, horns, color, auction month, year and the interaction effect between weight and feeder cattle quality characteristics in our input-demand model:

$$\begin{aligned} r_{F_{it}} &= \beta_0 + \beta_{LCF} LCF_{it} + \beta_{CF} CF_{it} + \beta_{wt} WT_i + \beta_{wt2} WT_i^2 + \beta_{mar} Margin_{t-1} + \\ &\beta_{lcf}\sigma_{LCF_t} + \beta_{cf}\sigma_{CF_t} + \beta_l LOTSIZE_i + \beta_{l2} LOTSIZE_i^2 + \beta_s Sex_i + \beta_{sw} Sex_i WT_i + \\ &\beta_p PreCon_i + \beta_{pw} PreCon_i WT_i + \beta_m Muscle_i + \beta_{mw} Muscle_i WT_i + \beta_f Frame_i + \\ &\beta_{fw} Frame_i WT_i + \beta_t Thrifty_i + \beta_{tw} Thrifty_i WT_i + \beta_h Horns_i + \beta_{hw} Horns_i WT_i + \\ &\beta_c COLOR_c + \beta_m MONTH_m + \beta_y Year_y + \varepsilon_{it} \end{aligned} \tag{3}$$

A detailed description of the above variables is given in Table 2.1.

Table 2.1 Description of variables in the empirical pricing model

Variable	Description
$r_{F_{it}}$	Feeder cattle price in lot i and time t
	Market Conditions
LCF_{it}	Live cattle futures contract price corresponding to the month the feeder cattle in lot i would be expected to be sold
CF_{it}	Average corn futures contract prices relevant over the feeding period for the feeder cattle in lot i
$Margin_{t-1}$	Actual 21-week cattle feeding margin for fed cattle marketed the previous week
σ_{LCF_t}	Coefficients of variation of daily prices for the past 21 weeks for live cattle futures
σ_{CF_t}	Coefficients of variation of daily prices for the past 21 weeks for corn futures
	Lot Characteristics
WT_i	Feeder cattle weight (average per head)
$LOTSIZE_i$	Number of head in the pen
Sex_i	Sex type. 1 denotes steers (default) (male cattle that has been neutered), 2 denotes heifer (female animal that has never had a calf), 3 denotes bull (mature male animal that is used for breeding), and 4 denotes stag (bull castrated after maturity)
	Quality Characteristics
$PreCon_i$	1 denotes preconditioned cattle, 0 denotes not preconditioned (default).
$Muscle_i$	Consist of three levels of muscle condition. 1 denotes light muscle, 2 denotes medium muscle (default), and 3 denotes heavy muscle.
$Frame_i$	Contain three levels of frame size. 1 denotes large frame size, 2 denotes medium frame size (default), and 3 denotes small frame size.
$Thrifty_i$	Contain two levels. 1 denotes thriftiness (default), 0 denotes unthrifty.
$Horns_i$	Horns = contains two levels. 1 denotes cattle with horns, 0 denotes cattle with no horns (default)
	Color/Breed
$COLOR_c$	Contain seven colors of feeder cattle. 1 denotes black(default), 2 denotes red, 3 denotes Hereford, 4 denotes brown, 5 denotes white, 8 denotes other and 9 denotes mix. (mix means feeder cattle has a mix of colors)
	Seasonality
$MONTH_m$	Contain seven months. 3 denotes March, 4 denotes April, 5 denotes May, 9 denotes September, 10 denotes October, 11 denotes November, 12 denotes December (default). Usually we take March, April and May as spring, September to December as the fall season.
$Year_y$	Year of sale. Contain seven years from 2011 (default) to 2017.

2.2 Decision-making Model

After the empirical pricing model, we could figure out how these factors may influence the feeder cattle price. In the table of feeder cattle price in difference season from 2011 to 2017 in Finger Lake Livestock Exchange, we notice that the feeder cattle prices in the fall season are always lower than those in the spring season. In this case, the farmer may want to raise feeder cattle for a longer time (from this fall to next spring) in order to earn a higher price. Notice that we define spring contains March, April and May, while fall contains September to December.

Table 2.2 Summary of feeder cattle price in difference seasons and sex types

Sex	**Steers**				**Heifers**			
Season	**Spring**		**Fall**		**Spring**		**Fall**	
Weight range(lbs)	Avg ($/cwt)	SD	Avg ($/cwt)	SD	Avg ($/cwt)	SD	Avg ($/cwt)	SD
300-399	166.92	45.05	158.64	45.55	154.48	39.49	137.21	36.11
400-499	164.62	43.12	154.00	41.79	154.95	37.02	137.16	35.74
500-599	164.99	39.90	149.88	41.84	145.08	34.30	132.90	36.14
600-699	153.98	37.30	138.03	36.76	147.15	35.71	122.89	33.15
700-799	143.86	29.45	128.30	33.08	135.23	32.57	119.31	29.36
800-899	135.92	28.33	123.16	30.57	126.74	27.02	119.16	27.06

Sources: Finger Lakes Livestock Exchange in Canandaigua, NY from 2011 to 2017.

However, raising feeder cattle from fall to spring will cost them some feeding inputs, like hay, grain and corns. Also, raising feeder cattle from fall to spring will increase the feeder cattle weight. Table 2.2 shows that heavier feeder cattle have lower price, since it costs more for heavier feeder cattle to gain one more pound compared with light feeder cattle.

Therefore, considering seasonal effect on feeder cattle price, feeding cost and weight discount on feeder cattle price, we build a decision-making model. This model helps farmer to choose an optimal time to sell their feeder cattle so that they could obtain higher profit. To this end, we compare the profit of selling the cattle in fall with that of selling the cattle six months later (in the spring). More specifically, we calculate:

$$\Delta Profit = Income_{spring} - Income_{fall} - Cost \tag{4}$$

Note that we estimate the difference between the profit of selling the cattle in fall, and that of selling it 6 months later (spring). To proceed, we define:

$$Income_{fall} = P_{fall} \times WT_{fall} \tag{5}$$

$$Income_{spring} = P_{spring} \times WT_{spring} = P_{spring} \times (WT_{fall} + r \times DAY) \tag{6}$$

Therefore, to calculate the incomes, we use the pricing analysis conducted before to estimate the feeder cattle price ($/cwt) in fall, and the feeder cattle price ($/cwt) 6 months later (in spring). By multiplying the price and the weight, we derive the incomes. The weight in spring equals to the weight in fall plus the gains in feeding period, which is the rate of gain per day times number of days in feeding period.

Next, we study the cost, which contains the fixed cost and daily feeding cost:

$$\begin{aligned} Cost &= \left(P_{c*fall} \times Q_c + P_{hay} \times Q_{hay}\right) \times DAY + Fix \qquad (7) \\ &= \left(P_{c*fall} \times 1.41\% \times WT_{average} + P_{hay} \times 1.41\% \times WT_{average}\right) \times DAY + Fix \\ &= \left(P_{c*fall} + P_{hay}\right) \times 1.41\% \times WT_{average} \times DAY + Fix \end{aligned}$$

We assume the quantity (pound) of corn and hay that one feeder cattle eat per day equals to 1.41% of its own weight. Since feeder cattle weight is increasing during the feeding period, we use the average weight in this period to calculate the corn and hay quantity. The fix cost here means the facility cost during the feeding period. The fix cost in our model is $33.93 in feeding period of six months. All these constants in (7) are determined by FINBIN (2019).

Finally, with (4), (5), (6), and (7), we have

$$\Delta Profit = \left(P_{spring} - P_{fall}\right) \times WT_{fall} + P_{spring} \times r \times DAY - \left(P_{c*fall} + P_{hay}\right) \times 1.41\% \times WT_{average} \times DAY - 33.93 \tag{8}$$

where

$\Delta Profit$ = the difference between the spring profit and fall profit. If it is positive, the spring profit is higher than the fall profit, which means that farmer should wait and sell the feeder cattle later (in spring).

P_{fall} = expected feeder cattle price ($/pound) at present time point (fall) based on pricing analysis

WT_{fall}= weight of feeder cattle in fall

P_{spring} = expected feeder cattle price ($/pound) at a future time point (next spring)

r = feeder cattle rate of gain per day, we set it as 2 pounds per day

DAY = the number of days from fall to spring, we assume it as 180 days (6 months)

P_{c*f} = the price of corn ($/pound) in fall, sourcing from USDA corn futures nearby contract

P_{hay} = the price of hay ($/pound) in fall

$WT_{average}$ = the average weight of WT_{fall} and WT_{spring}

Fix = fix cost of raising feeder cattle, which is $33.93

As a result, if the estimated $\Delta Profit$ is positive, selling the cattle 6 months later will bring more profits. Otherwise, it will be more beneficial to sell the cattle in fall. It should be noticed that the decisions made are highly dependent on the pricing analysis, which is conducted based on a set of considered covariates. We use the history data as training data to estimate the pricing model. Then given all the specific feeder cattle characteristics as input, we could estimate the feeder cattle price. Note that when we estimate the prices in fall and spring, the different inputs between these two is weight and month. Because these two variables change from fall to spring. Feeder cattle weight will increase in this six month, and month will also change from fall to spring. Other input variables like color, quality characteristics and market conditions will not change. Thus, the decision-making process is based on the conditions of the cattle, the market condition, and the farm conditions.

CHAPTER 3. Data

Our analysis is based on Transaction-level feeder cattle auction prices at the Finger Lakes Livestock Exchange in Canandaigua, NY during spring (Mar, Apr, and May) and fall (Sep, Oct, Nov, and Dec) from 2011 to 2017. The data includes transactions from 11,926 lots of feeder cattle (3,565 in spring and 8,163 in fall) encompassing 35,703 head (10,588 in spring and 25,115 in fall) over 54 auction dates.

During each lot's auction, feeder cattle prices were professionally evaluated and recorded for weight, lot size, time of sale, wean status, precondition status, sex, color, body condition score (BCS), frame size, muscling level, thriftiness, and buyer information. The data collection template is shown in Figure 3.1.

We only consider feeder cattle with average weight from 300lbs to 900lbs. Because this range is an approximation which matches the weight when they reach slaughter. This weight range has higher R-squared value, which means that they could explain most of the variance in the feeder cattle prices. (Dhuyvetter and Schroeder 2000;) In our dataset, 91% of the feeder cattle weight are in this range. In the overall 11,926 lot observations, 9393 observations contained complete data. That is our restricted dataset size. The average weight per head is 550.4 pounds.

In feeder cattle quality part, precondition is a 45-day program which will build the health status of the weaned calf prior to sale. According to the dataset, 52.85% of the observations are preconditioned. In our survey, we have three levels for muscle conditions: light, medium and heavy. Most of the observations are medium muscle conditions (76%) and heavy muscle conditions (23.4%). Our data collection template has three frame size levels: large, medium and small. 83.45% of feeder cattle are in large frame size, 15.75% of feeder cattle are in medium frame size, only 0.8% of feeder cattle are in small frame size. Most parts of the lots (40.19%) are steers, with 40.22% heifers, 19.09% bulls and only 0.5% stag.

Lot # ____________

Weight	
# head	
Time	

Wean PC Horns

Sex: S 1 H 2 B 3 Stag 4

Color: Black 1 Red 2 Herf 3 Brown 4

White 5 Hols 6 Dairy 7 Other 8 MIX 9

Uniformity of pen		
	YES = 1	NO = 0
Weight:		
Color:		
Breed:		

BCS: 1-3 1 4-6 2 >6 3

Frame: L 1 M 2 S 3

Muscle: 1 2 3 4

Thriftiness: Poor 1 Good 2

Price: ______________________

Buyer #: ______________________

Figure 3.1 Data collection template

The percentage of horns are very low, only 2.97% of the observations are with horns. What's more, the proportion of thriftiness is 96.17%.

Furthermore, we also consider the market conditions including the future price of corns and the future price of live cattle. The future prices of live cattle range from \$92.175/cwt to \$167.15/cwt with an average of \$131.835/cwt. And the future prices of corns range from \$3.348/bushel to \$7.99/bushel with an average of \$4.925/bushel. The summary statistics of the data are reported in Table 3.1.

In the Finger Lakes Livestock Exchange feeder cattle dataset, the average lot size is 2.5, which is far less than the feeder cattle lots in Kansas (Dhuyvetter, Schroeder ,2000). Figure 3.2 is the histogram of lot size in our dataset. From this histogram, 8229 lots are in lot size range from 0 to 5, 930 lots have more than 5 heads and less than 10 heads. Only 1 lot has the lot size 29 heads per lot. And the largest lot size is 61 heads per lot.

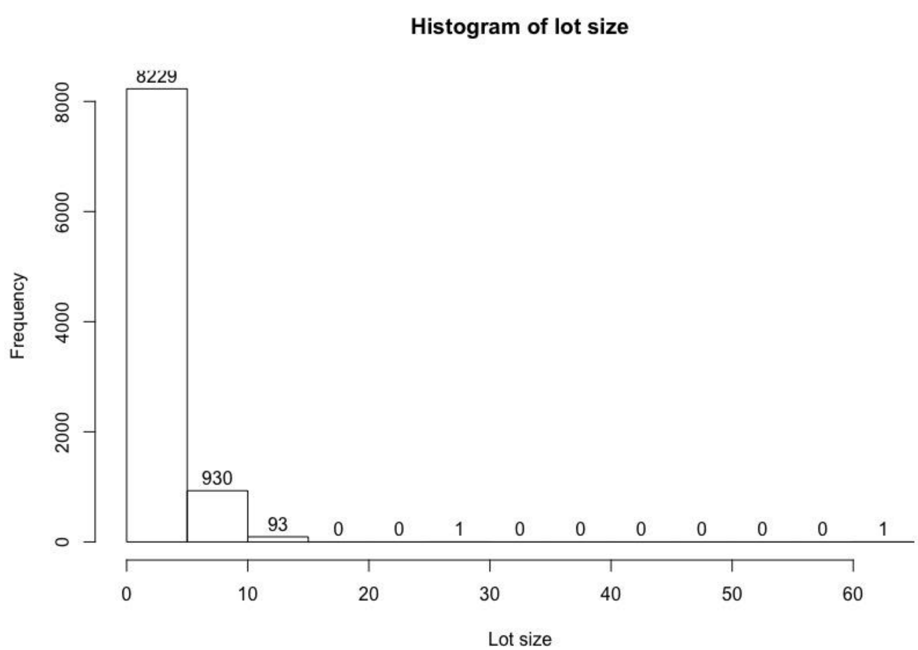

Figure 3.2 Histogram of lot size

Table 3.1 Summary of numeric variables in the dataset (N=9393)				
Variable	Mean	Standard Deviation	Minimum	Maximum
Feeder Cattle Price	141.606	39.763	20	345
		Lot Characteristics		
Weight(pounds/head)	550.408	140.931	300.455	899
Lot Size(head/lot)	2.513	2.331	1	61
		Market Conditions		
Live Cattle Futures	131.835	15.152	92.175	167.15
Corn Futures	4.925	1.299	3.348	7.99
Margin($/head)	46.63	189.57	-354.02	345.99
CV_C (%)	7.6	4.3	2.6	17.7
CV_LC (%)	3.8	1.2	1.5	6.2

Summary of category variables in the dataset (N=9393)				
Variable	Level Number	Number	Total Number	Proportion
		Cattle Characteristics		
Preconditioned	1	4964	9393	52.85%
No Preconditioned	0	4429	9393	47.15%
Muscle Light	1	56	9393	0.60%
Muscle Medium	2	7139	9393	76.00%
Muscle Heavy	3	2198	9393	23.40%
Frame Large	1	7838	9393	83.45%
Frame Medium	2	1479	9393	15.75%
Frame Small	3	76	9393	0.80%
Sex Steer	1	3775	9393	40.19%
Sex Heifer	2	3778	9393	40.22%
Sex Bull	3	1793	9393	19.09%
Sex Stag	4	47	9393	0.5%
Unthrifty	1	359	9393	3.83%
Thrifty	2	9034	9393	96.17%
Horns	1	279	9393	2.97%
No Horns	0	9114	9393	97.03%
Color: black	1	5866	9393	62.45%
Color: red	2	1216	9393	12.95%
Color: Hereford	3	1152	9393	12.26%
Color: brown	4	221	9393	2.35%
Color: white	5	207	9393	2.21%
Color: other	8	387	9393	4.12%
Color: mix	9	344	9393	3.66%

The average feeder cattle auction price is \$141.6/cwt ranging from \$20/cwt to \$345/cwt. The price history of feeder cattle in different weight ranges is shown in Figure 3.3. We divide the feeder cattle into three ranges according to the average weight per head: 300 pounds to 500 pounds, 500 pounds to 700 pounds, and 700 pounds to 900 pounds. The highest price occurred on March 10th, 2015 is \$345/cwt. There are many possible factors include poor exports, a strong dollar, large beef imports, rising supplies of competitive meat, record carcass weights, declining packer capacity, and delayed consumer resistance resulting the high feeder cattle price. Further, we include nearby contract feeder cattle future price on the auction price of New York State. The future price is higher than the auction price in New York State in most of time periods, and they both follow the same price pattern over time.

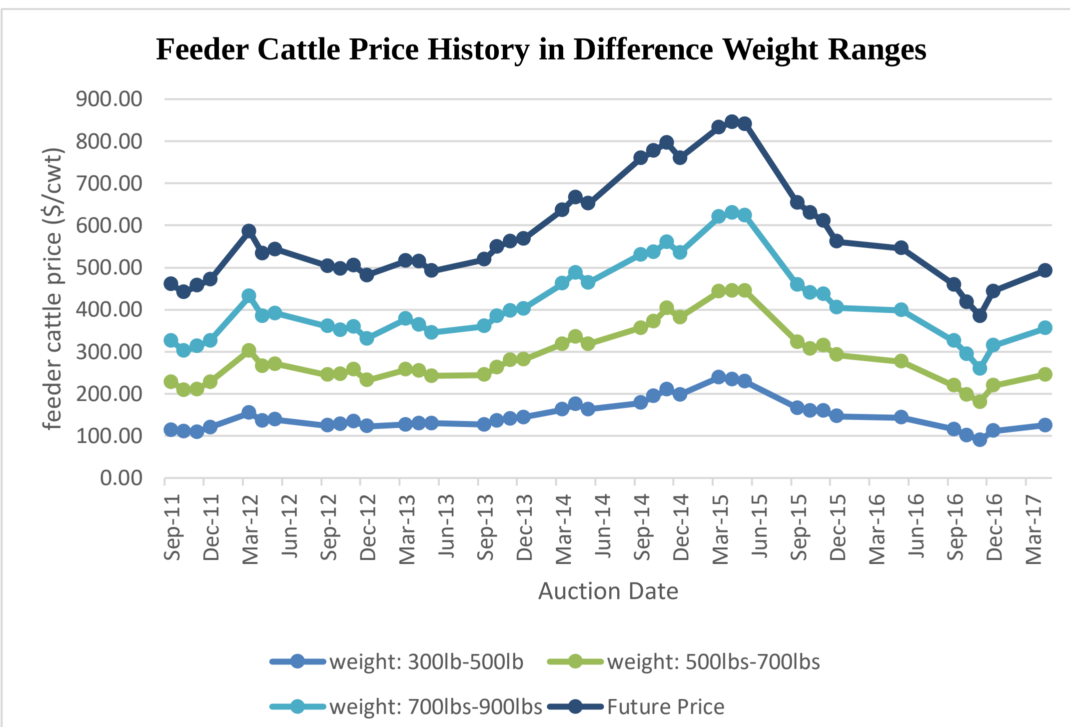

Figure 3.3 Price history of feeder cattle in different weight ranges

The basis table is provided in Figure 3.4. Basis is the difference between cash price and futures price. More specifically, it is the difference between local cash price and futures price of the futures contract with maturity closest to the present time on the same day. Basis is the distance between New York State feeder cattle auction price and the nearby contract feeder cattle future price. From this figure, at most of time periods, basis is negative. However, basis is positive in March and May 2015.

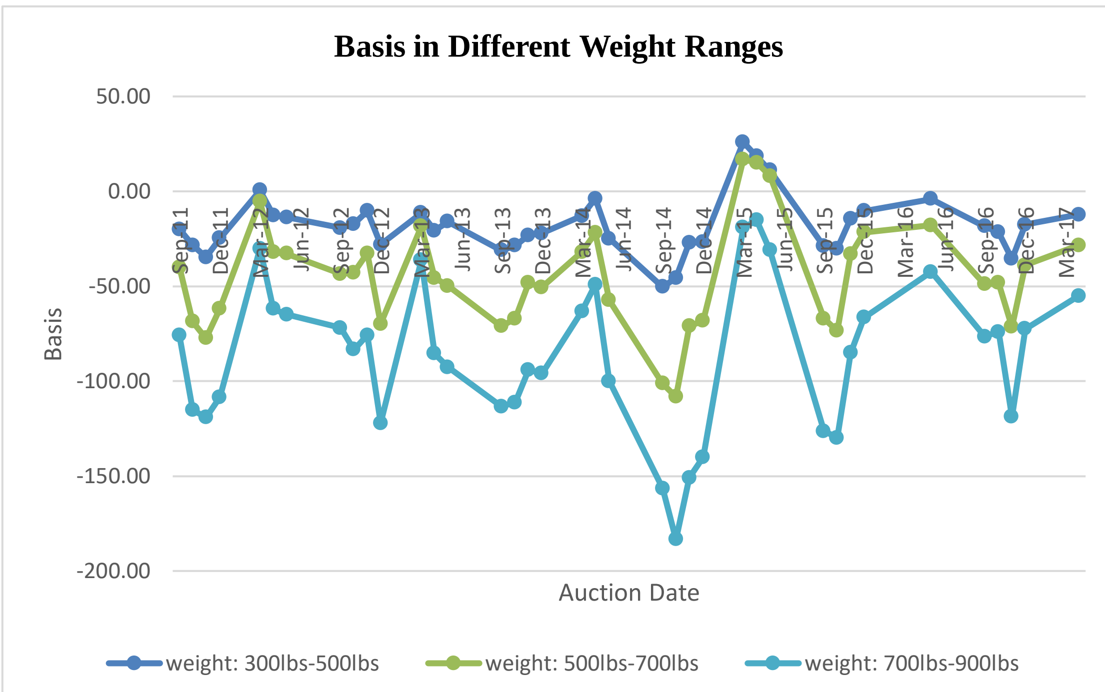

Figure 3.4 Basis Table

CHAPTER 4. Result and Discussion

4.1 Results of Pricing Analysis

In our empirical pricing model, we consider market characteristics, lot characteristics, feeder cattle quality characteristics, seasonality, and the interaction effects between weight and feeder cattle quality characteristics. This is different from Jing's pricing model (Jing Qian, Todd Schmit, 2014), which includes the interaction effects between weight and market characteristics, weight and lot characteristics, weight and quality characteristics. We omit theses interactions, since we already consider the weight effect on live cattle futures and corn futures. Margin, color, and month do not change with the feeder cattle weight. We also provide the results of pricing model without any interaction as a comparison. Regression results of three feeder cattle pricing models are shown in Table 4.1.

We also calculate elasticity for numeric variables in Table 4.2 and marginal effects for categorical variables in Table 4.3.

Table 4.1 Regression results of feeder cattle price determinants

Model	No interaction		Jing's Model		Our Pricing Model	
Variable	Estimate	Std.	Estimate	Std.	Estimate	Std.
(Intercept)	-15.863	8.589	-93.246***	10.958	-24.174**	9.051
Market Characteristics						
Live cattle futures(LCF)	1.734***	0.041	2.998***	0.071	1.792***	0.041
LCF*weight			-0.002***	0.000		
Corn futures(CF)	-7.034***	0.546	-19.135***	0.892	-7.066***	0.538
CF*weight			0.020***	0.001		
Margin	-0.006	0.004			-0.009*	0.004
Margin*weight			-0.0001***	0.000		
Margin*weight square			0.000***	0.000		
Live cattle CV	53.888	56.955			90.830	56.161
Live cattle CV*weight			0.270**	0.088		
Corn CV	109.241***	12.338			116.87***	12.172
Corn CV*weight			0.232***	0.020		
Lot Characteristics						
Weight	-0.087***	0.011	-0.013	0.021	-0.082***	0.013
Weight Square	0.000	0.000	0.000	0.000	0.000	0.000
Lot size	2.204***	0.132	2.111***	0.124	2.149***	0.130
Lot size square	-0.040***	0.006	-0.038***	0.006	-0.039***	0.006
Sex Heifer	-14.592***	0.480	-24.918***	1.868	-24.408***	1.942
Heifer*weight			0.019***	0.003	0.018***	0.003
Sex Bull	-11.672***	0.617	1.443	2.329	1.214	2.419
Bull*weight			-0.025***	0.004	-0.024***	0.004
Sex Stag	-18.649***	3.038	-3.497	17.309	-1.510	18.057
Stag*weight			-0.021	0.026	-0.025	0.026
Quality Characteristics						
Preconditioned (default no preconditioned)	5.788***	0.458	4.447***	1.714	8.479***	1.750
Precon*weight			0.002	0.003	-0.005	0.003
Heavy Muscled(MuscleH) (default medium muscled)	17.710***	2.779	61.715***	15.374	93.150***	15.960
MuscleH*weight			-0.071**	0.025	-0.125***	0.026
Light Muscled (MuscleL)	-9.876***	0.599	-5.793**	2.238	12.396***	2.053
MuscleL*weight			-0.011**	0.004	-0.042***	0.004
Large frame (FrameL) (default Medium frame)	-0.231	0.621	-3.032	2.378	-8.705***	2.384
FrameL*weight			0.009*	0.004	0.016***	0.004
Small frame (FrameS)	-16.346***	2.425	-29.196**	9.506	-24.709*	9.842
FrameS*weight			0.024	0.018	0.015	0.019
Unthrifty (default= thrifty)	-32.942***	1.139	-51.381***	4.366	-61.186***	4.523
Unthrifty*weight			0.035***	0.008	0.051***	0.008

Table 4.1 Regression results of feeder cattle price determinants (continued)

Horns (default=no horns)	-14.742***	1.260	-15.579***	4.821	-25.182***	5.001
Horns*weight			0.002	0.008	0.018*	0.009
Color/breed Characteristics (default = Black)						
Color Red	-4.111***	0.654	-7.046**	2.479	-4.236***	0.645
Red*weight			0.006	0.004		
Color Hereford	-17.537***	0.677	-32.312***	2.539	-17.678***	0.667
Hereford*weight			0.027***	0.004		
Brown	-1.590	1.428	-14.266*	5.980	-1.584	1.407
Brown*weight			0.024*	0.010		
White	-3.005*	1.463	-2.882	5.273	-3.080*	1.441
White*weight			-0.001	0.009		
Other	-25.902***	1.128	-51.842***	4.375	-25.922***	1.112
Other*weight			0.048***	0.008		
Mix	-9.438***	1.166	-20.240***	4.252	-9.968***	1.149
Mix*weight			0.020**	0.007		
Seasonal Characteristics (month default = December, year default = 2011)						
March	21.992***	1.175			23.225***	1.161
Mar*weight			0.040***	0.007		
Mar*weight square			0.000	0.000		
April	20.116***	1.134			21.222***	1.121
Apr*weight			0.042***	0.006		
Apr*weight square			0.000	0.000		
May	10.177***	1.041			10.838***	1.026
May*weight			-0.006	0.007		
May*weight square			0.000***	0.000		
September	-4.844***	1.051			-4.730***	1.037
Sep*weight			-0.027***	0.006		
Sep*weight square			0.000***	0.000		
October	-8.153***	0.989			-8.383***	0.974
Oct*weight			-0.037***	0.005		
Oct*weight square			0.000***	0.000		
November	0.974	0.823			0.884	0.812
Nov*weight			0.026***	0.005		
Nov*weight square			0.000***	0.000		
Year 2012	5.665***	1.167	3.926***	1.072	5.504***	1.151
Year 2013	-5.112***	1.523	-6.859***	1.361	-5.008***	1.501
Year 2014	0.091	1.476	-8.351***	1.431	-1.692	1.462
Year 2015	20.926***	2.470	10.923***	2.349	19.084***	2.440
Year 2016	20.614***	1.961	23.939***	1.852	20.995***	1.931
Year 2017	13.952***	2.390	18.250***	2.274	14.811***	2.355

Table 4.2 Elasticities of Continuous Variables (%)

Variable	Elasticity	Std. Err.	t-value	P value
Weight	-0.356	0.019	-18.68	0.000***
Lot Size	0.035	0.002	17.67	0.000***
Corn Futures	-0.246	0.019	-13.13	0.000***
Live Cattle Futures	1.669	0.038	43.65	0.000***
Corn Futures C.V.	0.063	0.007	9.602	0.000***
Live Cattle Futures C.V.	0.024	0.015	2.627	0.106
Margin	-0.003	0.001	-2.317	0.02*

*Significant codes: 0 '***', 0.001 '**', 0.01 '*'*

Table 4.3 Marginal Effects of Dummy Variables at Means ($/cwt)

Variable	Marginal Effects	Std. Err.	t-value	P value
Preconditioned	5.657	0.451	12.55	0.000***
Horns	-15.032	1.248	-12.05	0.000***
Sex Heifer	-14.359	0.474	-30.3	0.000***
Sex Bull	-12.208	0.611	-19.99	0.000***
Sex Stag	-15.324	4.241	-3.614	0.0003***
Color Red	-4.236	0.645	-6.570	0.000***
Color Hereford	-17.678	0.667	-26.503	0.000***
Color Brown	-1.584	1.407	-1.126	0.26
Color White	-3.080	1.441	-2.137	0.03*
Color Other	-25.922	1.112	-23.316	0.000***
Color Mix	-9.968	1.149	-8.674	0.000***
Frame Large	0.059	0.613	0.097	0.923
Frame Small	-16.542	2.492	-6.638	0.000***
Muscle Heavy	24.440	3.134	7.799	0.000***
Muscle Light	-10.635	0.594	-17.91	0.000***
unthrifty	-33.026	1.122	-29.44	0.000***

*Significant codes: 0 '***', 0.001 '**', 0.01 '*'*

4.2 Implications of Pricing Analysis

4.2.1 Lot Characteristics

The lot characteristics include sex type, lot, feeder cattle average weight per head, and lot size. According to the previous research, lot size and weight are expected to have quadratic impacts on feeder cattle price across weight. (eg Dhuyvetter and Schroeder 2000; Faminow and Gum 1986; Schultz et al. 2000). Therefore, we add *Lot Size*, *Lot Size Square, Weight, and Weight Square* into our pricing model.

In our pricing model, we consider the weight, weight squared and the interaction between weight and feeder cattle quality characteristics. The regression results show that weight has a significant effect on feeder cattle price at 99% significance level, while the weight square is not significant. Among all interactions, almost all interaction effects are significant at 99% significance level except the interaction between precondition and weight, and the interaction between weight and small frame size. The elasticity of weight is -0.356, which means if weight increases 10%, the feeder cattle price will decrease by 3.56%. This observation is consistent with the results in previous work (Rick J.Rasby, Darrell R. Mark, NebGuide): heavier feeder cattle have lower prices. The reason is that heavier feeder cattle tend to have poorer feed conversion, a marginal pound of weight on those cattle is less valuable.

From Table 4.3, the marginal effects of heifer, bull and stag are all negative, which suggests they all have negative effects on feeder cattle price compared to steer. In other words, the price of heifers and bulls are lower than the price of steers in the same weight conditions.

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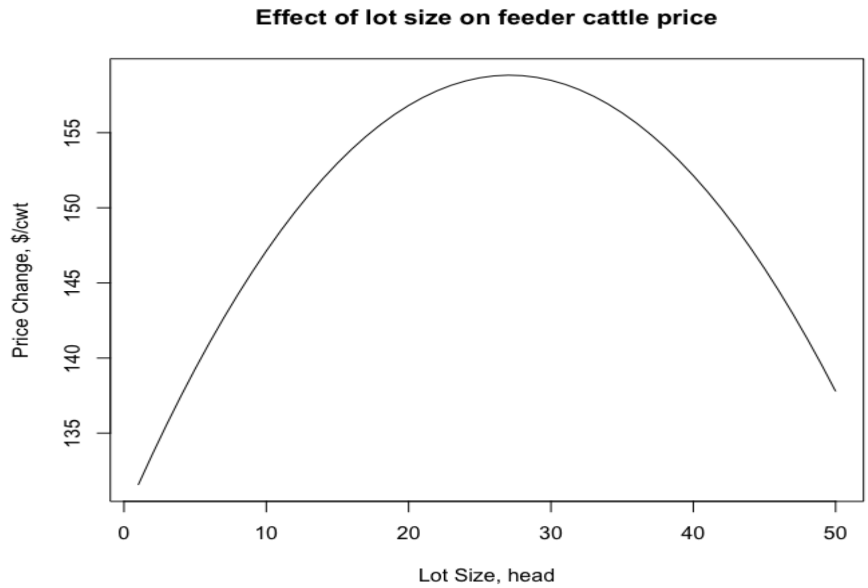

Figure 4.1 Effect of lot size on feeder cattle price

In Table 4.1, we notice that both lot size and lot size square have significant effects on feeder cattle price at 99% significance level in three pricing models. What's more, the elasticity of lot size is 0.035, which suggests that if lot size increases 10%, the feeder cattle price will increase by 0.35%. Therefore, the lot size has a positive effect on feeder cattle price.

Then, a plot for the effect of lot size on feeder cattle price is shown in Figure 4.1. Under this nonlinear relationship estimated in pricing analysis, the optimal lot size is 27 head per lot. This is different from the optimal lot size in the previous research (Faminow and Gum 1986; Schulz et al. 2010), which is around 60 (truck-load size). Such a discrepancy comes from the difference of the dataset used: the studied dataset contains many small-size lots.

4.2.2 Market Characteristics

Market characteristics contain live cattle futures, corn futures, margin, coefficients of variation for corn and coefficients of variation for live cattle.

It should be noticed that the elasticity of live cattle future price is significantly positive. Such strong positive relationship comes from the fact that after raising feeder cattle for a long time, the cattle will be sold as live cattle. Therefore, if the price of live cattle increases, the price of feeder cattle will increase as well. The elasticity of corn futures is -0.246, which indicates if the corn future price increases 10%, the feeder cattle price will decrease by 2.46%. This is non-surprising, since corn is the main input to feed cattle. The increased corn future price leads to the increase of feeding cost, and push farmers to sell the cattle, which decreases the price. Both corn futures and live cattle futures have significant effects on feeder cattle price at 99% confidence level.

The coefficients of variation for corn futures prices is significantly positive at the 99% confidence level, while the coefficients of variation for live cattle futures prices does not have significant effects on feeder cattle price (Table 4.1). The elasticity of these two variations are both positive. This result is different from Dhuyvetter and Schroeder (2000) which suggests negative cv-weight interaction effects. What's more, Dhuyvetter and Schroeder (2000) shows that the coefficients of variation for live cattle and corn prices had no economically important differential impacts on feeder cattle prices across the weight, while our results indicate that coefficients of variation for corn is significant with a p-value less than 0.01. This difference between the results is reasonable, since our dataset is significantly different from that in (Dhuyvetter and Schroeder, 2000): The range of our corn variation is from 2.6% to 17.7%, while the range of Dhuyvetter's data is from 0.95% to 21.76%. Also, our results of market variables are mainly consistent with Jing's result (Jing Qian, 2014).

4.2.3 Quality Characteristics

The quality characteristics include preconditioned, muscle condition, frame size, thriftiness, horns and color.

According to the results of our pricing model, the marginal effect of precondition is \$5.657/cwt, which means that if the feeder cattle is preconditioned, its price will increase \$5.657/cwt. In this way, precondition has a positive effect on the feeder cattle price, since precondition provides feeder cattle a health program with lots of vaccinations and dry feeds. At the average feeder cattle weight level (550.4lbs), horns receive a \$15.032/cwt discount to feeder cattle price compared with no horned feeder cattle.

The base of color is black, which is the most common color of feeder cattle. Compared to black, all the other colors have negative marginal effects. Color brown and white are not significant at 99% confidence level. As a result, color brown and white have no economically important differential impacts on feeder cattle prices. This makes sense since these two colors have very low proportions in feeder cattle colors: brown's proportion is 2.35% and white's proportion is only 2.21%.

Compared with medium frame size, large frame has a positive impact on the feeder cattle price and small frame size has a negative impact on the price. Also, heavy muscle has a significant positive effect on price while light muscle condition has significant negative effect on price compared with medium muscle condition. The marginal effect of unthrifty is -33.026, which means unthrifty leads to \$33.026 discount on price compared with thrifty.

4.2.4 Seasonality Characteristics

Seasonality consists of auction month and year. The auction month includes March, April, May, September, October, November and December (default). We define March, April, May as spring, and September to December as fall season. Since our dataset is the feeder cattle auction data from 2011 to 2017, the year variables contain from 2011(default) to 2017.

From Table 4.1, all the months except November have significant effects on feeder cattle price compared with December, which is same with the no interaction regression result. March, April and May have positive impact on feeder cattle price compared with December. September and October have negative impact on feeder cattle price compared with December. Among all the months, March has the highest positive effect on feeder cattle price.

It is consistent with the phenomenon we mentioned before that the price in spring season is higher than fall season. There are several reasons resulting in higher price in spring in the northeastern United States: feeding least-cost high-quality forages soon after calving; making the best use of low quality forages early in the winter during the immediate post-weaning period; rearing calves in a healthier environmental on pasture as opposed to rearing fall calves in a dry lot over the winter.

Year 2012, 2015, 2016 and 2017 have positive effects on the feeder cattle price while year 2013 and 2014 have negative effect on feeder cattle price compared with 2011.

4.3 Results of Decision-making Model

In the proposed decision-making model, profit contains three parts: income of selling feeder cattle in fall, income of selling feeder cattle in spring and cost. The cost here includes feeding cost and fix cost during feeding period. The proposed decision-making method estimates the expected profit of waiting another 6 months to sell the cattle, and compare it with the estimated expected profit of selling the cattle in fall season. Therefore, for each cattle at a specific time, the proposed model can provide suggestions on whether to sell the cattle based on cattle quality conditions, farm conditions, and the market conditions.

In the considered decision-making problem, weight is one of the most important features to determine whether to sell the cattle now or later, since it is the covariate that changes most significantly when the selling is postponed for 6 months. In the purposed model, we assume that the rate of gain is 2 pounds per day. The number of days of six months is 180 days, making the weight gain for one feeder cattle 360 pounds during this feeding period. However, there is not a single cut point for weight that works for all the cattle in terms of decision making, although we consider a linear model. The reason is that we also study the interactions between the weight and the quality conditions of feeder cattle. In other words, the proposed decision model provides different suggestions regarding the weight for cattle with different quality conditions, and thus is cattle-specific.

To efficiently implement the proposed model, an R function as a decision-making tool is provided, which takes the covariates like lot size, weight, live cattle futures, corn futures, preconditioned, muscle condition, thriftiness, horns, frame size, sex type, color and month as input, and returns the difference between the estimated profits of selling feeder cattle in fall and spring.

Also, we apply the decision-making method to the feeder cattle market dataset to evaluate the decisions made by the farmers. First, we apply the method to all the auctions that cattle sold in fall. It turns out that 55.33% of transactions were actually sold too early in the fall season. In other words, more profits will be gained, if the farmers wait till next spring to sell them. If we apply the method to all the cattle in the dataset, 42.1% of transactions are suggested to be sold 6 months later than the actual sold date.

The histogram of the estimated profit differences is shown in Figure 4.2**.** The blue bars represent the frequency and the orange lines show the cumulative percentage. We can see that most observations' profits are in range \$0-\$200, which means that the extra profit gain of selling the cattle in spring compared with in fall is \$0-\$200. This corresponds to the case where the farmer should feed the feeder cattle for another six months. When the estimated profit difference is negative, the farmer should sell the feeder cattle at the recorded date in the data. We can notice that, from the figure, most of the negative profits are in -\$400-\$0 range, and only a few of the observations' profits are less than -\$400. Therefore, the estimated profit difference between fall and spring is relatively small.

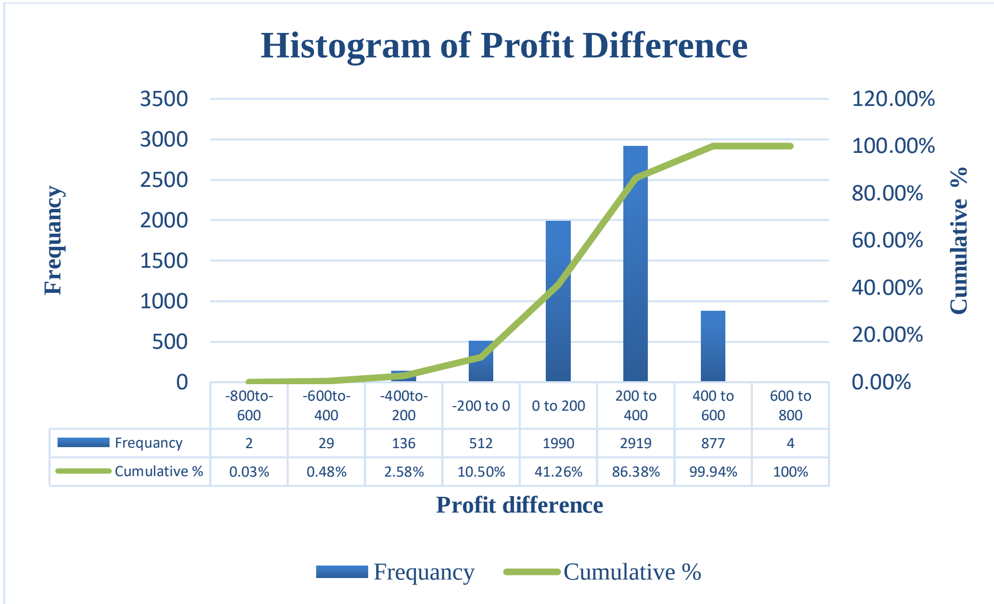

Figure 4.2 Histogram of Profit

4.4 Implications of Decision-making Model

In this section, we use two observations from our dataset to explain the purposed decision-making model, and the information of the cattle is provided in Table 4.4.

Table 4.4 Two Samples of Observations

observation	Date	Lot Size	Individual weight	Pre-condition	Horns	Sex
1	9/8/12	3	535.333	0	0	1
2	9/8/12	2	354.5	0	0	2
observation	**Color**	**Frame**	**Margin**	**Thrifty**	**Price**	**Muscle**
1	9	1	-4.069	2	126	2
2	3	1	-4.069	2	107	2
observation	**cv_live cattle**	**cv_corn**	**month**	**year**	**Livecattle future**	**Corn future**
1	0.021	0.135	9	12	136.125	7.990
2	0.021	0.135	9	12	132.475	7.963

First, we estimate both the present feeder cattle price by our pricing model based on all the characteristics in these two observations.

$P_{1now} = \$131.2674/cwt$

$P_{2now} = \$106.052/cwt$

$Income_{1now} = P_{1now} \times WT_{1now} = 131.2674 \times 535.333 \div 100 = \$702.718$

$Income_{2now} = P_{2now} \times WT_{2now} = 106.052 \times 354.4 \div 100 = \$375.954$

Second, we assume that the rate of gain for feeder cattle weight is 2 pounds per day, and that the number of days from fall (September) to next spring (March) is 180 days. So, the total weight gain of feeder cattle from fall to next spring is 360 pounds. Then, the future weight of our two samples are:

$WT_{1future} = 535.333 + 360 = 895.333\ lbs$

$WT_{2future} = 354.5 + 360 = 714.5\ lbs$

The factors that change from fall to spring are weight and month. Therefore, we update the feeder cattle weight and month in our regression model to get the estimated price in next spring.

$P_{1future} = \$130.9378/cwt$

$P_{2future} = \$119.9979/cwt$

$$Income_{1future} = P_{1future} \times WT_{1future} = 130.9378 \times 895.333 \div 100 = \$1172.329$$

$$Income_{2future} = P_{2future} \times WT_{2future} = 119.9979 \times 714.5 \div 100 = \$857.3849$$

Third, we consider the cost during these six months, which include feed cost and fix cost. The feed cost contains the corn cost and hay cost, and the fix cost is \$33.93 according to "Barnyard & Backyards winter 2007". The quantity of corns and hay that one feeder cattle eat in one day is 1.41% of the weight. (FINBIN (2019). Center for Farm Financial Management: University of Minnesota.)

$$Cost_1 = \left(P_{c*now} \times 1.41\% \times WT_{average} + P_{hay} \times 1.41\% \times WT_{average}\right) \times DAY + Fix$$

$$Cost_1 = (7.99 \div 56 \times 1.41\% \times 895.333 + 8.13 \div 56 \times 1.41\% \times 895.333) \times 180 + 33.93 = 556.5184$$

$$Cost_2 = (7.99 \div 56 \times 1.41\% \times 534.5 + 8.13 \div 56 \times 1.41\% \times 534.5) \times 180 + 33.93 = 423.1213$$

Finally, based on all the incomes and costs, we can figure out the profit between fall and spring.

$$\Delta Profit_1 = Income_{1future} - Income_{1now} - Cost_1 = -\$86.9062$$

$$\Delta Profit_2 = Income_{2future} - Income_{2now} - Cost_2 = \$58.3096$$

In short, based on the profits, observation 1 should be sold now, and observation 2 should be sold six months later.

Therefore, we provide a decision-making tool to help farmers decide the optimal time point to sell their feeder cattle. The farmer only needs to input the feeder cattle quality characteristics, market characteristics, and lot characteristics. Then a result suggesting whether to sell the feeder cattle now or 6 months later comes out. Farmers can also input the feeding cost and fix cost for their specific situation to better implement our model.

CHAPTER 5. Conclusion

We provide a decision-making strategy for farmers in terms of when to sell the feeder cattle. The proposed method will benefit farmers by offering suggestions on selling strategies. The method is built on a thorough and careful pricing analysis for feeder calves, which is also meaningful for other related future works.

The decision-making method is built on a variety of covariates including lot size, individual weight, live cattle futures, corn futures, preconditioned, horns, sex type, color, frame, muscle, thriftiness, month and year. According to the input of the covariates, the method will provide both the future incomes and the current incomes of selling the cattle, by estimating the current price, current weight, future price, future weight, and the related costs based on pricing regression model. In the empirical pricing model, all the coefficients indicating the conditions of the calves are significant in our pricing analysis, including the color, sex, muscle, frame type, and horn type. Accordingly, the price of the calves differs over the types of cattle. This conclusion is considered in our decision-making method, which generates selling strategies for every cattle.

The weight of the cattle turns out to be one of the most important covariates for the decision making of farmers. When a farmer chooses to wait for 6 months, the weight will be the characteristics of the cattle that changes the most, and thus affects the decisions. In our pricing analysis, while the coefficients of weight are negative, most of the interactions between weight and other cattle condition covariates have negative coefficients. As a result, generally, the higher the weight, the lower the price will be. This is reasonable since as the cattle get older, the price per cwt gets lower.

Further, according to our analysis, the prices in spring tend to be higher than the price in fall. The reason is that within the same year, farmers will spend 6more months of efforts in feeding calves when selling them in fall compared to spring. Thus, the price will be higher. However, it is not always right to sell cattle in fall, since we also need to take the costs and the drop of the price into consideration. The proposed model correctly studies this problem for decision-making.

As a result, farmers can use the proposed method by inputting the condition of the cattle, farm, and the market condition. Then, the method can give suggestions on whether to sell the cattle in Fall or wait for another 6 months. This decision-making tool will benefit farmers by providing suggestions on the selling strategies to achieve higher profits.

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